L-Band Digital Link for Air Traffic Services Data Communications

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What is LDL?

- **Systems being considered by the Technical Assessment Group (TAG) of the FCS:**
  - **L-band solutions: P34 derivative, LDL**
  - **Satellite solutions: Iridium, Inmarsat**
  - **C-band solutions for airport surface: 802.XX**
- **LDL = L-Band Digital Link**
  - **Upper layers almost the same as VDL Mode 3: to short-circuit the specification/validation process**
  - **Physical layer similar to Universal Access Tranceiver (UAT): but lower data rate**

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Rationale for LDL

- VHF Band is already very congested
- L-Band is already allocated for civil aviation
  - 960-1024 MHz or 960-976 MHz
  - Currently for navigation (ARNS)
  - Potential change at next WRC
- Uses same (or very similar) upper layers as VDL M3
- Flexibility to provide data and/or voice in varying proportions (including 100%)
- No need for 25 kHz channelization
  - Allows for physical layer optimization
  - Allows for “improvement” of certain VDL M3 difficulties

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LDL versus VDL M3: Physical Layer Comparison

	VDL Mode 3	LDL
Frequency Band	118 -137 MHz	960 – 1024 MHz
Modulation Type	D8PSK	Binary CPFSK
Bit Rate	31.5 kbps	62.5 kbps *
Eb/No (including losses)	17 dB	11 dB **
Cochannel D/U	20 dB	6 - 9 dB

* To be optimized. Can be anywhere between 37.5 kbps to 100 kbps.
** Noncoherent detection. Could be improved with more complex demodulator

Link Budget Comparison: Up Link

	VDL Mode 3	LDL
Power (15 Watts) (dBm)	42	42
Cable Loss (dB)	-2	-2
Antenna Gain (dBi)	6	6
EIRP (dBm)	46	46
FSPL (120 NM) (dB)	-122	-139
Antenna Gain (dB)	-4	-4
Cable Loss (dB)	-3	-3
Received Power (dBm)	-83	-100
Bit Rate (dBHz)	45	48
Eb (dBmJ)	-128	-148
External NF (dB)	20	N/A
Internal NF (dB)	14	5
Total NF (dB)	19	5
No (dBm/Hz)	-155	-169
Received Eb/No (dB)	27	21
Theoretical Eb/No (dB)	13	9
Implementation Losses (dB)	4	2
Required Eb/No (dB)	17	11
Margin (dB)	10	10

VDLM3 @ 130 MHz
LDL @ 972 MHz

62.5 kbps versus
31.5 kbps

External Noise
Negligible at L-Band

Channel BER = 10^{-3}

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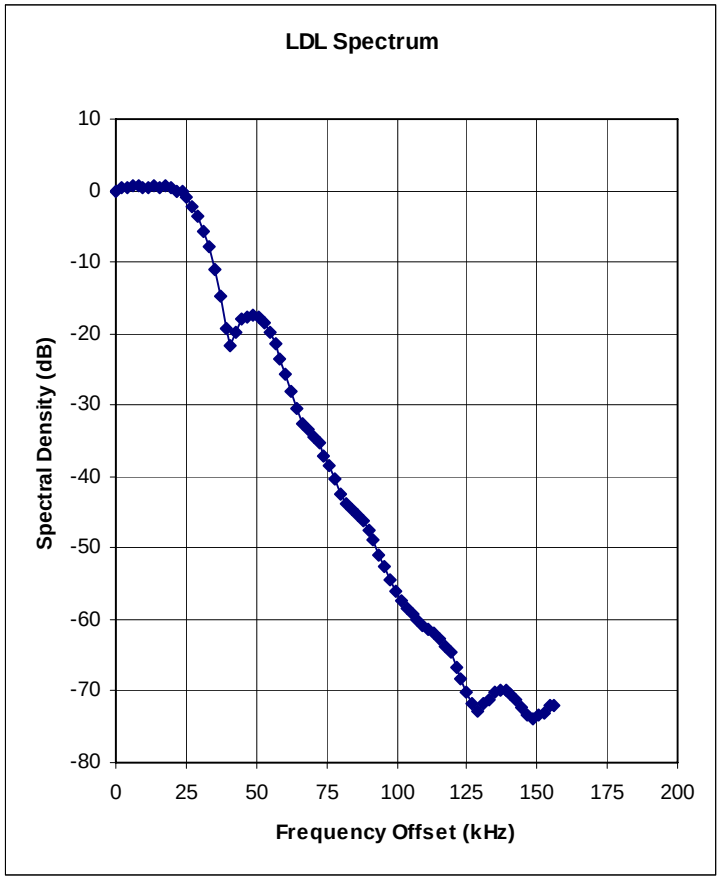
LDL Spectrum

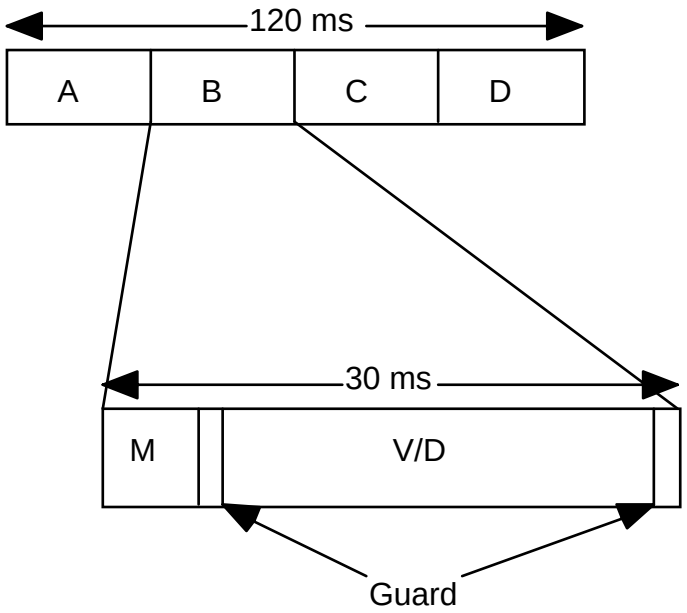


Proposed channel separation
= 83.33 kHz

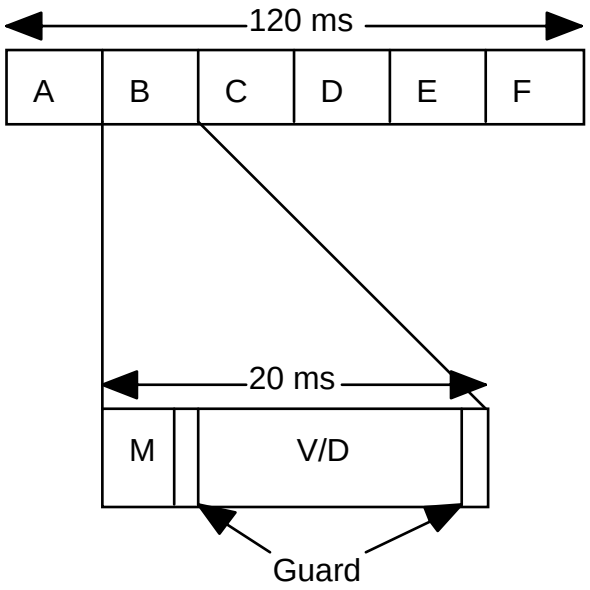
12 frequency channels per MHz

Time Slot Structure

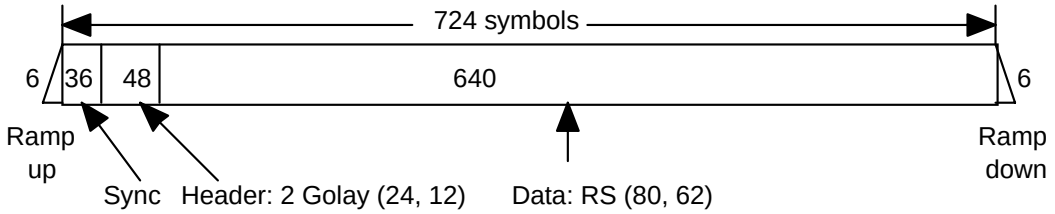
VDL Mode 3



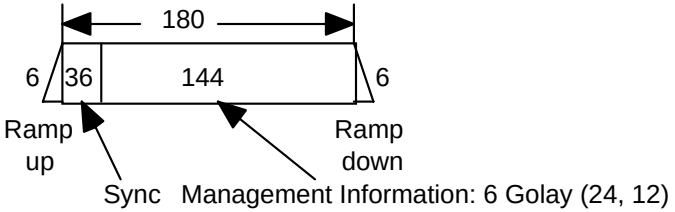
LDL **(62.5 kbps)**



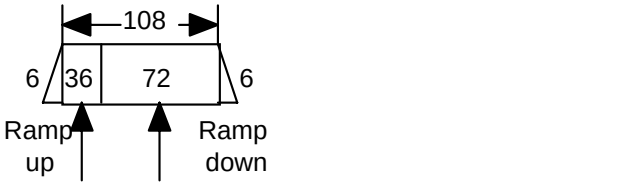
Burst Structure



1 Golay (24, 12) RS (72, 62) **V/D Data Burst**



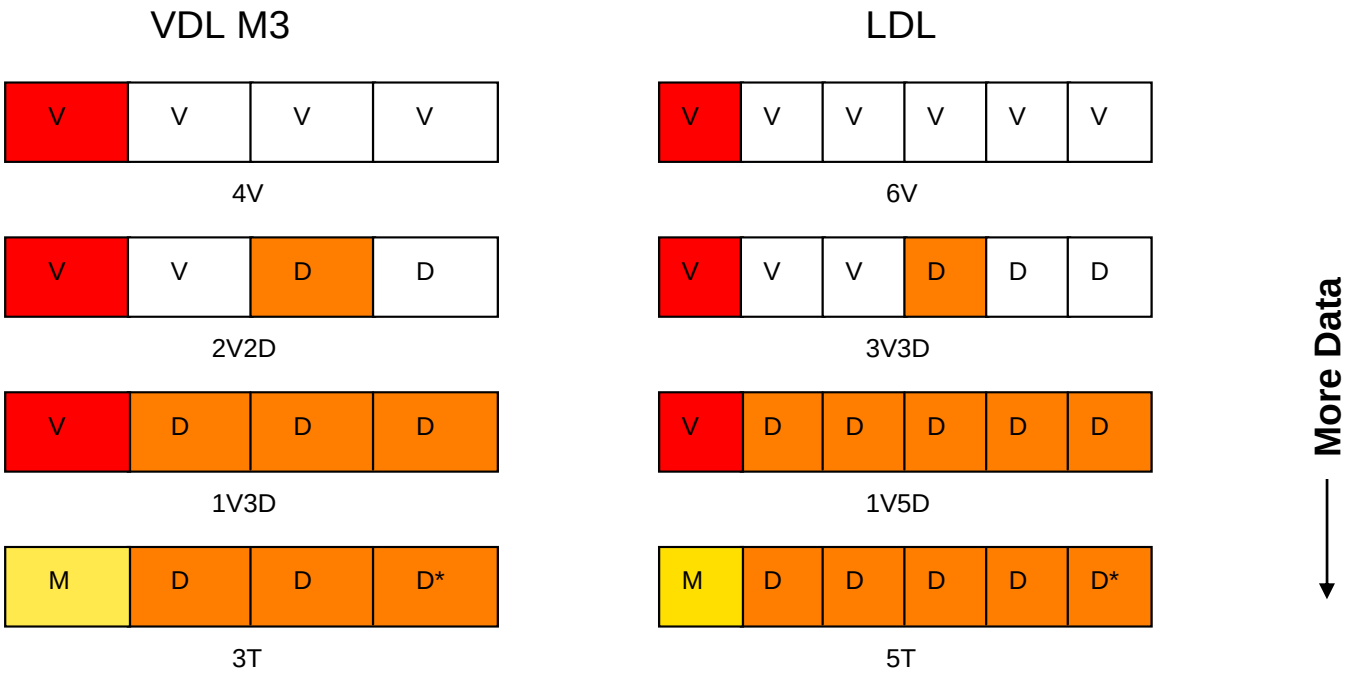
4 Golay (24, 12) **M Up Link Burst**



2 Golay (24, 12) **M Down Link Burst**

Values for VDL Mode 3 in color

Configurations



* Can also carry digitized voice

Voice (if any) and data are noninterfering

Data Capacity

- LDL
  - Data capacity per link (1V5D or 5T)
    - 8x62x5/0.120 = 20.67 kbps
  - Total data capacity per MHz
    - 20.67x12 = 248 kbps
- VDL Mode 3
  - Data capacity per link (1V3D or 3T)
    - 8x62x3/0.120 = 12.4 kbps
  - Total data capacity per MHz
    - 12.4x40 = 496 kbps

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Capacity (Continued)

- LDL seems to have ½ the capacity, but
- There may be more spectrum available (64 vs. 19 MHz)
- The much better cochannel performance of LDL will allow greater frequency reuse
  - Preliminary analysis shows this more than makes up the 2:1 capacity difference when viewed over many cells (i.e., kbps/MHz/NM^2)
- System definitions based of other bit rates may give more or less capacity: requires further study
  - For example, 37.5 kbps allows 4-slot structure with 2 dB more sensitivity and same total capacity/MHz

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Comparisons with VDL Modes 2 & 3

- ***Versus* Mode 2**
  - **Better data priority scheme**
  - **Better latency ?**
  - **If voice included, no mutual interference**
- ***Versus* Mode 3: More bits in M bursts and headers and higher data rate provide…**
  - **Simplified net entry for multiradio platforms**
  - **Possibly no need for "truncated voice" mode**
  - **More robust data: RS(80, 62) *versus* RS(72, 62)**
  - **Longer data messages: maximum 31 bursts *versus* 15 bursts (1500 byte IP packet fits in 25 bursts)**

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Interference Issues

- **LDL must coexist in the L-band on a noninterfering basis. Potential victims include:**
  - **DME (about 300 kHz BW on 1 MHz centers)**
    - **Don't assign frequencies near multiples of 1 MHz, or**
    - **Excise frequencies based on local DME frequency assignments**
  - **UAT (about 1 MHz BW at 978 MHz)**
    - **Don't assign a block of frequencies near 978 MHz**
- **Some issues need further study**
  - **Noise floor emissions may cause interference on cosite platforms (collocated LDL and victim)**

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Further Studies

- FCS Technical Assessment Group (ITT)
  - L-band propagation study
  - Interference to/from LDL (e.g., DME, UAT)
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  - LDL synchronization procedure
  - Ramp up/down requirements
  - Improved demodulation performance
  - More advanced (turbo?) coding

Summary

- LDL is a viable candidate for future ATS data communications
  - May include voice if desired
- May be “faster-to-market” due to similarity with VDL Mode 3
- Basic idea being assessed by FCS TAG
- LDL is not completely defined
  - Subject to fine-tuning
  - Details of some formats and protocols need to be worked out

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